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The Rocks of Oland

GEOLOGICALLY CONSIDERED

BY

VICKERS OBERHOLTZER, A. M., Ph. D. (Rostock)

PRINTED FOR THE AUTHOR
PHILADELPHIA, PA.
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Vickers Oberholtzer, A.M. Ph.D.

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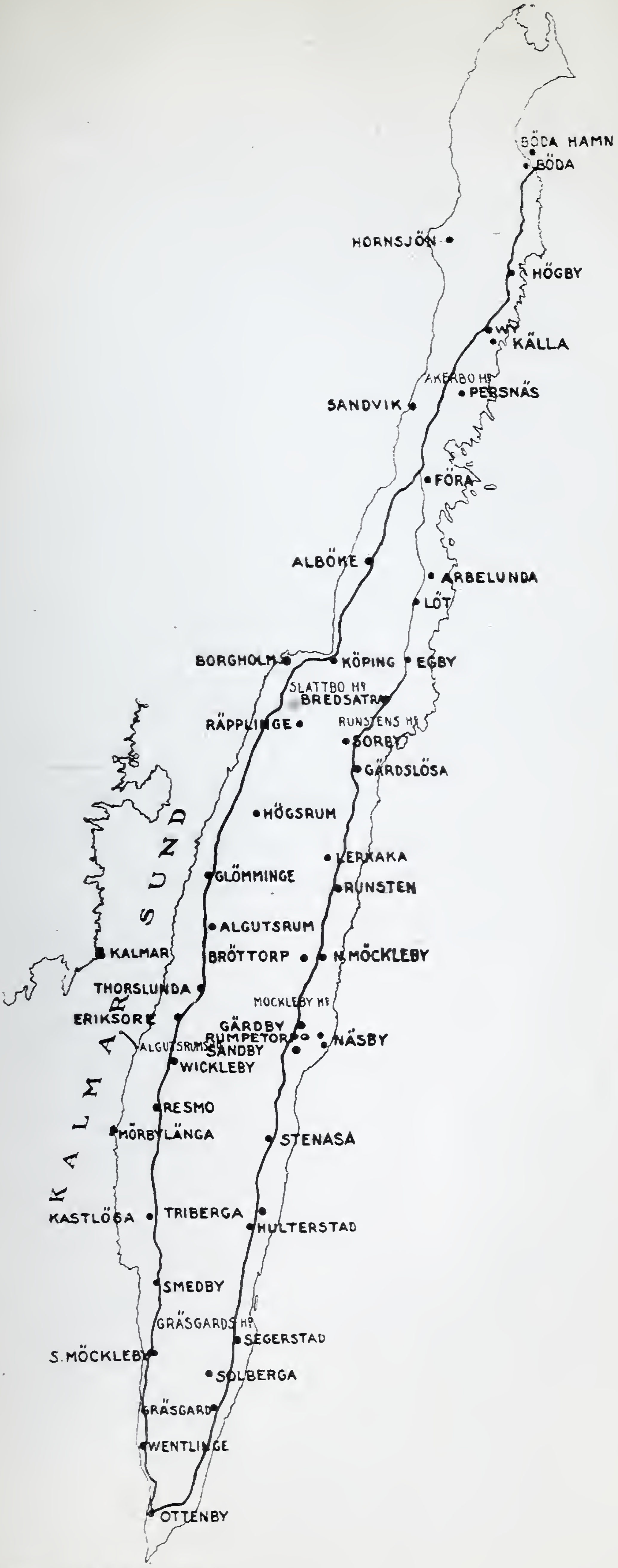

THE ISLAND OF OLAND

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Foreword.

The geological excursions in the island of Oland, lying off the eastern coast of Sweden, of which the ensuing pages are the product, were made in the summer of 1894, while the author was a student in the German universities. The fossils collected at this time were lately placed on deposit with the Academy of Natural Sciences of Philadelphia, where they are now on view, and can be referred to by those whose investigations may carry them into the same or related fields of research.

The Rocks of Oland Geologically Considered.

In no other part of the world are the Orthoceras limestones richer in fossils than in the eastern part of Oland. This island is situated in the Baltic Sea, only a few kilometers distant from, and almost parallel with, the east coast of Sweden. It extends from S. S. W. to N. N. E. between 56 degrees 12 minutes and 57 degrees 22 minutes north latitude, and 0 degrees 55 minutes and 1 degree 40 minutes longitude west from Stockholm.

It is about 150 kilometers, *i. e.*, about 90 miles in length, and in width varies from 3 to 15 kilometers. It is separated from the mainland by Kalmar Sund, a shallow channel in the primordial sandstone that lies under the succeeding conformable layers of the Under Silurian formation of which the island consists.

Before entering upon a discussion of the different rock layers of the island it may be interesting to make brief mention of the general characteristics and habits of the 38,000 people living there. Its only town is Borgholm, which is a pretty little bathing resort having 900 inhabitants, with steamers running daily to and from the mainland. The wharf, when the boats come and go, presents a busy scene; the people at these times come in from neighboring parts of the island. Their way of harnessing horses and cattle, or rather of using them without harness, is so unique that it is a matter of wonder how they pull at all. Sometimes they pull with a board placed across the horns; at others with a tongue that runs between the legs and is fastened to the neck by a rope and a stick which acts as a collar or yoke. The carriage harness for horses consists chiefly of hames (no collar is used usually) rope traces and lines. There are no blinds, check rein or holding back straps. The horse must keep out of the way of the home-made little wagon in going down the very slight hills of the island. The horses are of a distinctive breed, small and fleet of foot. They trot for miles without encouragement and are the chief product of the island, being raised largely for export. The colts always run loose after the wagon. As many as five often follow one team. This continual exercise of the colt develops the hardy and enduring horse for which the island has a reputation. These are the horses used almost entirely by the Swedish government for cavalry service.

On Oland as in Germany the women have equal labor rights with the man and apparently have the same strength and ambition. They are to be seen everywhere ploughing or digging with the men. The ploughing is done with a crooked contrivance of wood with an iron point. This has but one handle which the ploughman or woman holds with one hand, while driving with the other. It stirs up the ground in a very modest manner, and occasionally leaps entirely out as it strikes a stone. The harrows are a collection of wooden teeth which merely tickle the surface of the earth. These primitive tools are perhaps a necessity on account of the thinness of the soil in many parts, the bed rock being only a few inches beneath the surface.

The Olanders are in other respects back of the world's great vanguard in the matter of living utensils. They hook their water out of wells with a bucket and a long pole. They cook on a three-legged iron tripod which sits over an open fire. They sleep in a bed which serves as a bench in daytime, and which at night is a kind of low box with board sides like a coffin. The ceilings of their turf or straw-covered houses are low, and the doors often so small that one must stoop to go in or out; carpets and other essentials of some more advanced civilizations are luxuries unappreciated and for the most part unknown. A traveller, on entering a small village, will see nothing but a long row of red barns with a few geese and some cattle in the highway; and sometimes, too, a graveyard and a big white-washed stone church. He will wonder where the people live. The houses are nearly all behind the barns and the only entrance is through these buildings. After having gotten in the appearance is rather cosy. A farmer often has two or three little one-story houses in a group. He will live in one in winter, another in summer; or cook in one and sleep in another according to his fancy.

The timber growth of the island is usually short and scanty; hazel bushes being the chief trees in this stone-covered land. Large trees can only find root room in the sands at the northern and southern extremities of the island. It may be of interest to add that both ends of the island are owned by the King of Sweden and used for hunting parks. They are separated from the rest of the island by high stone walls to prevent the escape of game.

The most curious things on the island are the windmills, of which there are sometimes eight or ten in a single village. There is no water power, but the wind makes up the deficiency, for its sweep is unobstructed. These mills are used to grind the grain and polish the hard limestone from the quarries before shipment. Their simplicity deserves some attention. Each one rests on a heavy square of timber which serves as a pivot, so that the mill can be freely turned to face the wind. The tower or mill is made of boards, and within it are placed the millstones which do the grinding. Some contain only one pair of stones, others as many as three, and, although the space is so limited that not much room remains to store the grain and meal, the process of grinding is so slow that the requirements in this way are not great. The arms which catch the wind, four in number, are stupendous. They reach to within a few inches of the ground and run high into the air, the hub being set as near the top of the tower as possible. The diameter of the wheel on small mills is only about thirty feet, but on the large ones must surely be from fifty to sixty feet. On a windy day when these arms are sweeping around one thinks of a flying machine and must use caution in approaching them. A stranger feels quite relieved when the windmill village is safely passed, for the wheels swing around swiftly and silently beside the road and are without the slightest guard or fence. The miller regulates his speed by the method of the sailor. When the wind is strong he takes in a reef. The arms of the mill are about four feet broad and are either shingle paddles or of canvas. When the miller sees a storm coming he removes some paddles, or folds the canvas and continues to grind at the same rate of speed. When the wind changes the miller turns the wheel and tower to meet it by pushing on a long piece of timber extending from the back of the mill. Even the stairway by which the miller mounts his tower hangs loose without attachment to the ground, the only support for this apparently top heavy steeple of industry being the one bottom pivot.

A traveller will find the people, for the most part, full of curiosity, for they seldom see strangers, but they are always pleasant and respectful. In out of the way places there will be uncertainty among them whether to run or stare, but they usually end in staring. Many of the inhabitants speak English which they have learned as sailors; not a few have been for a time in California and other parts of the United States seeking their fortunes. But they invariably return home to enjoy their little incomes in a place where their money will go so far and bring them so much. It is in fact seldom seen, swapping being the usual method of trade.

Geologically the island is a remarkable Under Silurian fossil bed. The rock, for the most part an impure limestone, at all points is rather near the surface, and over great tracts lies perfectly flat to form a rocky floor miles in extent, which is broken at places only by a slight covering of moss, a grass-filled crack or a few scattered glacial boulders. The loose stones in the farming districts are taken off the layers by ploughing owing to the extremely thin coating of soil, and are everywhere piled up in the shape of stone walls, the size of the fields seeming to vary with the supply of loose stones in the neighborhood. At some points even this expedient is inadequate, and here and there are great piles of them, raised as high as a two-story house with the accumulation of years.

On account of its rich fossiliferous deposits the island offers many attractions to the geologist, though in the practical field difficulties occur which have earlier prevented full study and investigation. These difficulties are chiefly a lack of means of transportation, there being no railroad or other public method of conveyance. The post wagons which traverse the two roads of the island almost daily are not allowed to carry passengers or bags of fossil-containing rock. The two roads of the island of which the natives speak as the inside road and the outside road confuse one at first, since an examination of the map reveals but one road which makes a circuit of the entire island.

The best method of transportation will be found to be by boat. This, however, is tedious, as it is always necessary to return to Kalmar on the mainland and take another steamer. It possesses the advantage of giving an opportunity for exchanging a load of stone for one of food and living supplies.

In a scientific way much has been effected of late by the Sveriges Geologiska Undersokning, especially in the classification of the strata. This was first done by Linnarsson in 1875-6 and Tullberg in 1882, and palæontologically by Moberg in 1890.

The opportunities for a close observation of the formations are not as abundant as might be desired on account of the lack of deep quarries and other excavations which are so constant an aid to the geologist. This is due not always to the unsuitable quality of the stone for technical uses, but to the limited demand which exists for it, and its superabundance at the surface. It is thus difficult to learn definitely as to the thickness of the different strata, and the relation in which they at all times stand to each other. Most of the chief points for observation are the normal outcrops which usually show a dip of from one to two degrees towards the east, although Moberg observes in his article entitled "Anteckningar om Olands Ortocerkalk," published by the Sveriges Geologiska Undersokning in 1890, that a dip towards the west is by no means seldom. On a walk taken across the barren plain of which much of the southern half of the island consists, from Eriksore to Stenasa, this slight rolling character of the strata was clearly noted. This was particularly the case as the east coast was approached. Here there is a series of long stretched out undulations which are fully confirmatory of Moberg's observation. These undulations are also to be observed in the Under Silurian of western New England. The Oland formation can, however, be better compared with that extending from Lake Erie over Cincinnati into Tennessee; here, according to Safford, Newberry and Orton, rocks of the Hudson River and Trenton eras are exposed to view. It was then, for the most part, raised above the sea level and so remained through the rest of the Silurian age and part of the Devonian as an island in the continental seas. That this was the time of the uplift is proved by the absence of Upper Silurian and Devonian over this region. The Oland uplift, though in comparison comparatively small, no doubt took place at the same time and differs from the uplift in the central parts of the United States in never again having been submerged, unless indeed some later formations on the island have been entirely swept away by the great Scandinavian glacier which, as is well known, during the ice age moved southward over it.

The only thing on the island in the way of irregularities or hills are the so-called Klinten or cliffs which extend along the west coast. At the southern point of the island they are not more than five feet high; going northward there is a gradual increase until Borgholm is reached. Here they attain a considerable height and are somewhat grotesquely worn at certain points; so peculiar is this that several have received special names as "Noah's Ark" and "The Ship" because of a fancied resemblance to these objects. From this point they gradually fall away and are again at the water level at the northern extremity of the island.

These cliffs offer the best opportunity for a view of the different layers at Eriksore, in the locality of the castle ruins at Borgholm, in the vicinity of Köping, on the shore west of Ottenby and at some other points. They afford for the most part profiles of only the older strata of the island. There are quarries near Sodra Möckleby in the alum slates, and in a rather non-fossiliferous limestone which is used in the manufacture of cement, one near Sandby where a building stone is procured, another near Arbelunda with the same object in view, still another at Sandvik for millstones, and others at Persnas and Wy.

The normal outcrops of the island cover vast expanses which are occasionally dotted with glacial drift. Where there is soil it is of so slight a depth, as has been noted, that the layers are broken up in the process of agriculture. It is thus that the walls which everywhere surround the fields and the stones which stand in frequent heaps may in general be taken to be a sure index of the surface rock in almost any given locality.

As earlier remarked the dip is in the main towards the east so that in general in crossing the island from west to east younger layers are met with, but, as Moberg observes, this order is not always consecutive since at some places the younger strata have been entirely torn away, or only now remain in the form of cakes. This was thought by Moberg to have been due to the action of the weather. The extreme thinness of some of the layers and the softness, caused to a great extent by the great quantity of fossils contained, makes this theory probable. This condition of the rock would also have rendered easy, irregular wearing away by glacial action. That much of Oland's strata was torn away in this manner is clearly proven by A. Remele in his investigations (published in the Festschrift für die Fünfzigjährige Jubelfeier der Forstakademie Eberswalde, 1880), concerning the glacial drift of Eberswalde when he found several varieties of Lituites in boulders which undoubtedly came from Oland. In general, however, this direction from west to east can be easily followed, as was observed on walks taken from Sodra Möckleby to Segerstad and from Borgholm to Sorby where all the layers one after the other were met.

Underlying the orthoceras limestones of the island and coming to the surface only along the west coast is the Cambrian formation, resting no doubt on granite and gneiss which, however, are not exposed here.

Only the upper layers of the Cambrian formation are to be observed. The under layers of the primordial zone, that is Fucoid sandstone forms the bed of Kalmar Sund and only occurs fast on the island in the vicinity of Borgholm. Along the coast opposite Ottenby is a natural rocky wall, the so-called "Klinten" previously mentioned. It is here about three meters in height and is made up of layers of limestone and glauconite containing slate intermixed with Ceratopyge limestone. The under part of the wall at and below the water line consists of Dictyonema skiffer or shale. It, however, at this point contains little or no remains of Dictyonema flabellaforme. As one passes up the coast northward to Gronhogen one finds the Olenid or Dictyonema shale, appearing above the water line and filled with Dictyonema flabellaforme. This shale extends as far north as Sodra Möckleby and Little Smedby. Moberg reports finding in the Dictyonema shales the trilobites, Ceratopyge forficula and Shumardia pusilla which have also been found in the Ceratopyge skiffer of Norway, showing entire agreement between the two. In the Scandinavian Dictyonema shales at Sandby I had the good fortune to find Acerocare ecorne which Professor Ludgren of the University of Lund, Sweden, kindly identified for me, adding it was the only species of trilobite as yet found in the Dictyonema skiffer of Sweden proper; in Norway two varieties of Obolella and one Acrotreta have been found in addition. From the above it is to be seen that Ceratopyge limestone and Dictyonema shales cannot be palæontologically separated and form, according to Brogger, the transition of the Primordial zone to the Orthoceras limestones. The Ceratopygekalk corresponds in age to the Chazy limestone of the United States; they have, however, little in common.

At Sodra Möckleby the Dictyonema shale becomes bituminous and overlies a pure bituminous limestone from which Pelturia scabrides and Obolus apolluris were collected; beneath this appeared the Under Alum skiffer. This should contain Paradoxides; none however were found. The bituminous alum slates and limestone are both mined extensively at this point, crystallized alum and quick lime being produced in large quantity. We have here a fine example of the providence of nature, in providing an exceptionally pure limestone and the fuel with which to burn it; both in the same quarry. But this is not all, for the ash from the bituminous alum slate, which is, of course, the fuel, on lixiviation yields an alum water. The lixiviation of this ash is carried out in a series of great wooden vats. The process is the same as that used so largely in applied chemistry especially throughout Germany in the manufacture of beet sugar, the series of vats being connected in such a way that fresh water always runs first into a vat containing an extracted shale. The solvent passes through a series of vats of progressive gradation. In order to attain a maximum of concentration the alum solution is brought finally into the vat containing ash fresh from the kiln. This solution is then evaporated in great lead-lined vessels. Pure crystallized alum is thus produced in large quantity at little cost.

Further to the north the bituminous alum shales fail, and we have, as stated by Sjögren, a Swede, the first geologist to visit this island, in an article entitled "Anteckningar om Oland ett bitrag till Sveriges geologi" which he published in the scientific Swedish journal, "Ofversigt af Köngl. Vetenskaps-Akademiens Förhandlingar" for 1871, page 673, that in the vicinity of Borgholm it (the Primordial Zone) could be divided into three layers namely:

A. Sandstone, white and granulous.

B. Shale sandstone with strata of limey sandstone lying between.

C. Grayish clay shale containing gypsum with strata lying between, consisting of limestone and quartz. From the shaly sandstone, or B he obtained Paradoxides Tessini and from C Paradoxides Olandicus. The priority of age of these two trilobites has been a question since much discussed by Swedish geologists, and has been written about by Linnarsson, Nathorst, Anderson and Tullberg and by the great German geologist, Professor Dames. Tullberg appears to have proved conclusively that Paradoxides Olandicus is the older inasmuch as he found its remains in the sandstone obtained by boring to a depth of 135 feet at this point. One would expect to find here layers containing Olenellus Kjernlfi, the oldest trilobite met with in Sweden. Its presence, however, is not known with certainty, showing that the oldest layers of the Cambrian probably do not occur on the island.

The orthoceras limestones of the Under Silurian are exposed to view over the entire island excepting in this narrow strip of Cambrian along the west coast, the sand covered extremities and the echinosphaerite limestone which lies along the east coast, extending northward from Böda Hamn. The orthoceras limestone consists of alternating layers of red and gray. These colors were at first taken to be the characteristics of and were utilized by Linnarsson and Tullberg for the formation of a system. They both divided it into four layers, Linnarsson designating them: Over Gray, Over Red, Under Gray and Under Red: Tullberg: Over Gray glauconite free, Over Red, Under Gray glauconite bearing, and Lowest Strata. Thus Linnarsson took a layer of red to be the oldest of the orthoceras limestones and both placed upon the lowest strata a layer of gray which was followed by a younger red and finally also by a younger gray. This color system was later found to be not completely borne out by fuller investigations, there being sometimes in one of these color divisions two or more separate faunas. It was also observed that the colors changed in rocks which occupied the same relative position and contained the same fossil species. The imperfections of the old system in these respects were well pointed out by Moberg, as a result of his careful studies and excursions on the island, in his book entitled "Anteckningar om Oland's Ortocerkalk." The change of color in the same layer I clearly observed on the southern half of the west coast. This variation can be partially explained by the fact that it occurs in the Under Red or the lowest of the orthoceras limestones, which is what might be regarded as a transition layer, produced at the change of a shale into a limestone formation. It differs largely also in composition at many points, but nowhere is it a pure limestone. The deposit opposite Sodra Möckleby is of a blue gray color, and being highly siliceous is ground and barreled to be labeled Portland cement. A very similar limestone found in the neighborhood of Oland's "Alun bruk" is quarried for stove linings, it having, owing to its porosity, the property of withstanding a considerable amount of heat without cracking. It is most probably a silico-magnesium limestone. This layer, Under Red, was divided into two divisions palæontologically by Moberg, namely: Planilimbatakalk and Limbatakalk on account of Megalaspis planilimbata occurring most plentifully in the under layers and Megalaspis limbata in the over layers. Owing to the extreme hardness of the Under Red and its complete resistance to the action of the weather it forms a large part of the great unbroken barren tract which extends over the southern half of the island as a rock floor, perfectly level excepting for the slight dip of from one to two degrees towards the east. This level plain is called "alfvar" by the natives whose cattle pick at will the grass which finds root in an occasional crevice. The Under Red orthoceras limestone lies entirely conformable to the underlying shales or Cambrian, the only change being that of a very pure limestone to one dolomitic and impure.

The following layer or Under Gray glauconite-bearing limestone, according to Tullberg, is designated Asaphuskalk by Moberg on account of the great number of varieties belonging to the genus Asaphus found here. This layer forms without doubt all the most sterile tracts, or "alfvar" on the northern half of the island. Owing to the difficulty which attends the removal of fossils from this rock in most parts, and the lack of investigation here it no doubt contains many undescribed forms.

As my observations and collections were chiefly made in the younger and more tractable layers we shall also pass quickly over the Over Red. It will suffice to say that Moberg designated it Platyurus kalk on account of the richly occurring Asaphus platyurus. This is followed by a thin so-called "ofvergangslager," or transition layer which consists of a complexity of strata with an often changing color—red, white, gray or flamingo. In it is found a rich, little known fauna. To judge from the rock variety as well as the fauna this as yet unexamined layer forms a nice transition between the platyuruskalken and the youngest of the orthoceras limestones, the so-called Over Gray which occurs in fast layers at many places along the east coast. Some parts of this division show an extraordinary richness in fossils, while others are almost barren. It would appear that these parts might be of two distinct formations, therefore an endeavor was made to work out these layers palæontologically.

The fossiliferous layers consist of a pure, finely crystalline, readily splitting, gray, compact limestone, the fracture of which is so characteristic that anyone who has become familiar with it could not mistake it for any other stone on the island. The stone can be dressed out in almost any desired direction and the fossils contained are in a perfect state of preservation. This, taken together with the ease with which the stone splits, makes the collector's harvest exceptionally fine. The softness of this layer makes it weather rapidly, but owing to the usually great size of the fossils in it they are not to be obtained in a weathered out state. On this account it works up much more readily into soil than the other formations and the western edge of this layer marks the beginning of the rich strip of farm land which extends along the east coast. This stone was observed as occurring in the south part of the island as far up as the vicinity of Sorby, in greater abundance near Lerkaka, and the outcrop was nearly continuous at Runsten, Nord Möckelby and Sandby. Further to the south the outcrop seems to be smaller, and indeed is met only in isolated districts as at a point near Solberga and Nasby. In all probability it is everywhere here the underlying rock, though covered in most places by glacial drift. In the northern part of the island above Sorby the formation is earth covered, but crops out again at a point a little north of Löt and can be well observed near the main road about opposite Arbelunda. The formation was again seen as an outcrop at the water's edge of a little bay north of Högby, and yet further to the north in the neighborhood of a small lake east of the Hornsjön, but is at this point mostly covered by a thick layer of peat. Further north the formations are for the most part overlaid with sand which, as at the southern end of the island, are used for timber growth. It will be noted by a glance at the map that these localities which have been mentioned form a rather direct line from north to south at a more or less uniform distance from the east coast.

The most common fossils found in this layer are: Illænus centaurus Ang. from which Moberg named this Centauruskalk, or Illænus chiron as designated by Holm recently; Ptychopyge aciculata Ang., Ptychopyge tecticaudata Stein., Orthoceras vaginatum, Lituites lituus Montf., Cheirurus exul, and two varieties of Euomphalus, namely marginalis and obvallatus. In addition to these there are in the collection made in this layer: Ampyx nasutus, Remopleurides species, Lituites perfectus, Caryocystites testudinaria, Hyolithes acutus, Pleurotomaria elliptica, Orthoceras regulare, Orth. centrale, Orth. scabridum, Orth. conicum, Leptæna sp., Nileus armadillo, Cyrtometopus tumidus, several species of Discoceras, Bellerophon sp., Eurypterus or Pterygotus sp. and others including several brachiopods and endoceras, one closely resembling Endoceras belemnitiforme which was described by Holm and found in this same layer. This specimen differs from that of Holm's in several particulars and is certainly not identical. The finding of a Eurypterus (species as yet undetermined) is of particular interest, as it has not been previously found so early in the Under Silurian, in fact not until the transition rocks to the Upper Silurian are reached. That the specimen was taken from this layer is fully proven by the well remembered fact that it came from a farmer's gate post (in a back field, however), which I am sorry to say was completely demolished in the capture. In the same post were found almost all the fossils mentioned as being most plentiful in this layer, Centauruskalk. The post was about two feet wide, one foot thick and three feet high. Over an hour was spent in this act of vandalism with hammer and chisel, and the post reduced to pieces which were for the most part too small even for throwing at crows, there being high hopes entertained of finding something else rare in the same place. As stone is abundant on Oland, the farmer was not notified of the deed and surely when he came by that way next time would think someone had gone hopelessly mad on the spot.

Strombolituitekalk, according to Moberg, is the next succeeding or uppermost layer of the Over Gray orthoceras limestone. It is rather non-fossiliferous and in contradistinction to the readily splitting Centauruskalk just described, is an extremely tough, dull, blue gray limestone. The beds are very distinctly stratified into loosely attached layers which are separated by a shaly deposit. In these seams are found nearly all the fossils of this formation which are therefore generally in a poor state of preservation. The fracture of the stone of this layer is uneven and could not be confused with that of the other layer just described, and owing to its extreme hardness is polished and shipped away for use as floors and steps. This layer crops out in the neighborhood of Sandby where it runs into the sea and on account of its hardness and its marked property of resisting disintegrating action forms a slight extension in the coast line at this point. The formation is met again in the north, beginning at Arbelunda, where there is an extensive quarry in this stone and forms a normal outcrop between the main road and the sea for the distance of several miles.

This is a barren tract of considerable extent attaining its maximum width near Wy, where there are also large quarries. The formation at this point extends half across the island, its westernmost limit being marked by the growth of trees and other vegetation. The most northern point at which this layer was observed was in a quarry near the main road close by Dödevi. By again consulting the map it will be noted that this layer likewise forms a more or less direct line a little east of the more fossiliferous layer mentioned above.

The condition of this layer respecting fossils varies considerably. At Sandby the shaly argillaceous seams are rather fossiliferous, at Arbelunda practically fossil free, while at Wy and west of Munketorp several species are met which were not observed further south.

The fauna of this layer includes: Strombolituites undulatus, Nileus armadillo, Hyolithes acutus, Illænus centaurus, Echinosphærites aurantium, Orthoceras regulare, Cyroceras or Trochoceras species, Lituites lituus, also several brachiopods and corals.

On comparing the fauna from these two layers there seems to be sufficient evidence to class them as distinctly separate, but endeavors to find the dividing line between them were unsuccessful, as there seems to be no point at which one can observe them in contact. It would appear, however, that the richly fossiliferous layer was the older, as at a point between Nord Möckleby and Bröttorp where the latter is found in a low-lying pasture, while the rather non-fossiliferous and harder layer, when it comes to the surface somewhat south of this point, occupies a much more elevated position. But the latter outcrop is bounded on one side by the Over Red and on the other by the sea. Stray blocks of the richly fossiliferous layer are met with scattered over this district, though it is not to be found fast here. In the north where the rather non-fossiliferous layer is exposed over such a vast expanse somewhat the same conditions are to be observed.

Near Arbelunda the two layers occur, and here the richly fossiliferous layer again occupies a somewhat lower position to the west of the other formation. Still further to the north, following the same outcrop, the relations of the two layers are not to be observed as the fossiliferous layer is failing until noticed at the watermark in a bay north of Högby and at a point near a little lake east of the Hornsjön. Setting aside the small exposure near Högby the fossiliferous layer was not seen east of the hard interstratified layer and nowhere is its outcrop extensive. The layer, which at Arbelunda is nearly fossil free (only one orthoceras was found during a search in the quarry here) gradually becomes more fossiliferous as one travels to the north.

Beginning at Wy a transition fauna, notably Echinosphærites aurantium and a few brachiopods, is observed and joins on the east at a point north of Högby an undoubtedly distinct and younger formation which has been called by Linnarsson Cystidenkalk. A western branch of this great outcrop takes on more of the characteristics of the softer layer, extends to the northern limits already mentioned and disappears. The eastern arm which has joined the Echinosphærite limestone passes yet further to the north than the western arm in a narrow strip, and is met on the west by Over Red. The fossils which are found here have more the character of the Echinosphæritekalk or limestone and bear little resemblance to those which occur in it further south.

These Over Gray layers in the orthoceras limestone of the east coast of Oland were regarded by Moberg as two separate formations, and were named by him Centaurus kalk (the softer fossiliferous limestone) and Strombolituite kalk (the harder rather non-fossiliferous). He questions, however, if it is proper to make the division having most probably not made a complete examination. The circumstance of the Strombolituites undulatus not occurring in any of the older formations would seem to show that some time had elapsed between the deposit of the two layers. This fossil was described by Remele in the Zeitschrift der Deutschen Geol. Gesl. für 1881, p. 191, and found by him in the Echinosphæritekalk of Esthland, Russia; further it has been noted in no limestone younger than this, and adds proof to the supposition of Dames (Zeitschrift der Deutschen Geol. Gesl. für 1881, p. 415) that the Echinosphærite formation in Esthland is of the same age as the Over Gray of Oland, and was not deposited simultaneously with the Echinosphærite limestone of Oland which is the next following layer. This he proves by the lituites which occur here for the first time in large numbers and the rare occurrence of Orthoceras vignaten, the most characteristic fossil of the orthoceras limestones. Taking the Over Gray as a whole this comparison is rather uncertain, but when it is divided into two layers, the fossiliferous or Centaurus limestone and, in comparison only, rather non-fossiliferous or Strombolituite limestone, we recall that the members of this genus Lituites, Lituites lituus in particular, occur most largely in the upper layer, while Strombolituites undulatus is not found in the upper layer. It is also to be observed that no remains of Orth. vig. were obtained from the upper layer. These additional facts make the Echinosphærite limestone of Russia undoubtedly correspond in age with the Strombolituite limestone, or topmost layer of the orthoceras limestone of Oland. The comparison with the Russian deposit which was formed in the same sea gives the perhaps needed fuller proof that the Over Gray division of the orthoceras limestone should be divided into two separate layers, and in fact shows that the upper layer is not a true orthoceras limestone but must be placed separately above them making the rather non-fossiliferous layer of the Over Gray limestone of Oland nearly the exact counterpart of the Echinosphærite limestone of Esthland, Russia. The fossils of the next succeeding layer, Cystidenkalk of Oland place it on an equality with the Brandskiffer, or next succeeding layer in Russia. The only palæontological difference existing between the Brandskiffer of Russia and the Cystidenkalk of Oland and the Echinosphærite kalk of Russia and the Strombolituite kalk of Oland is in the abundance of and not in the character of the fossil species which occur. This is most notable with Echinosphærites aurantium which practically fills the rock called Cystidenkalk of Oland and the Echinosphærite kalk of Russia. This circumstance led to the false supposition that they were of like age.

The youngest fast layer on the island of Oland is the Cystiden limestone just mentioned. This is found over a rather limited district on a jut of land in the north. The district extends out farther east into the sea than any other part of the island. It begins in the south at a point of land opposite Munketorp, reaches north to Böda Hamn, and probably extends to the northern extremity of the island, but on account of the heavy coating of sand, which starts a little to the north of Böda it cannot be observed. It is a hard, gray limestone which clings tenaciously to its contained fossils, but is readily disintegrated by the elements. At places it was observed split up so that the outcrop resembled great mosaics. This splitting may either be due to thin seams of shale running through the rock, or to a large proportion of aluminous matter. Under both these conditions it would absorb water, which by the expansion of freezing would soon split the stone. The Cystiden limestone is to be seen to the best advantage at low water mark and the exposure is most interesting at Böda Hamn. Here the layer is unusually rich in Echinosphærites which present a beautiful appearance as seen by the observer on the shore, extending out beneath the surface of the water as far as the eye can reach. The sight was one long to be remembered and made one think of the common name sea lily given some living members of the same genus. The bud-like balls expanding to the bursting point by the waves, and the crystalline interior sparkling like diamonds beneath the water equalled in purity and beauty the appearance of any living crinoid. Portions of the rock are made up almost entirely of the Echinosphærite balls. Other layers contain no heads but simply the stems mixed with a great variety of brachiopods, while some parts of the formation are practically fossil free. On account of the peculiar tenacity of the stone, the fossils of this formation cannot be easily obtained by cracking, but as they are to be found in plentiful quantities weathered out recourse to this method is unnecessary. The richest harvests are to be obtained in the neighborhood of the beach at Böda Hamn where they have been washed out by the waves. Good specimens are also to be had weathered out of the exposed rock at various points in the formation. This is not an orthoceras limestone in any sense as fossils of that genus practically fail. Only one indeterminable species was observed.

The following varieties were found most common in this formation: Echinosphærites aurantium, Caryocystis granatum, Orthis testudinaria, Chætetes sp. Occurring less frequently we have: Ampyx nasutus, Caryocystites testudinaria, Orthis biforata, Orthis dorsata, Orthis demissa, Orthis basalis, Orthis imbrex, Orthisina sp., Bellerophon sp., Leptæna sericia, Euomphalus sp., Conularia sp., Chasmops macroura, Phacops sp., Illænus sp., and several corals.

SOME YOUNGER UNDER SILURIAN BLOCKS WHICH OCCUR IN THE SOUTH.

There occur in certain parts of the island, chiefly in the south on the east coast, numerous blocks which from the character of their fossils indicate them to be of a younger formation. These have been the subject of much discussion. They were observed by Sjögren on his journey to the island as early as 1851 and were designated as

Chasmopskalken owing to the great number of the trilobites, Chasmops macroura and Chasmops conicophthalmus, found fossil in this limestone. This name was adopted unquestioningly by later investigators and was in use until a very recent time. It was earlier by nearly all writers assumed that these blocks belonged to a fast layer somewhere in the vicinity, although none were able to place it. Holm in 1882 was thought to have discovered an outcrop in the neighborhood of Hulterstad, as mentioned in an article written by him and entitled "En Geologisk Paleontologisk Resa pa Oland" for the "Ofversigt af Köngl. Vetenskaps-Akademiens Förhandlingar" No. 7, p. 69, but this was not supported by later examinations. If not occurring fast on the island itself the formation was supposed to exist at a short distance from the shore, and the presence of the erratic blocks was thus accounted for. The latest publication on this subject, however, is disastrous to these theories, and presents us with an entirely new and apparently more reasonable explanation.

Joh. Gunnar Andersson, who has been making valuable investigations recently in regard to the glacial action in the southern part of the island (published in the O. K. V. A. Förhandlingar No. 8, p. 521) concludes that these blocks consist not of one but of several formations. He has made a study of the moraines of this locality and is led to state that these blocks have been deposited here only as glacial drift, as is the case with the Diluvial Geschiebe occurring at various places over North Germany. This theory, according to my observations, seems to be the correct one, for, although some of the blocks bear a resemblance to Chasmops in their fauna, others are distinctly different both palæontologically and lithologically. A collector will soon notice that the species here are of great variety. One block will be met which is rich in two or three varieties, while the next will contain none of them, but will likely be as rich in some others. It is possible, therefore, to go from block to block and obtain a wider collection than could reasonably be looked for in any one formation. Blocks for instance were met containing only gasteropods, another Leptæna sp., another cup corals, another Orthis argentia, another Echinosphærites aurantium, etc.; which would seem to justify and fully support the theory that these are only drift stones from the various formations. Liberally intermixed with these are granitic glacial boulders. This theory also finds strong support in the petrographical differences of these blocks; while some are hard as niggerheads, others can be broken to pieces by the hand. Continuing, some are of pure unaltered limestone others are partly silicified. The color also varies greatly. I observed in one place a boulder of pure, white, hard coral limestone, while near it stood a soft block of a brownish yellow color. Other blocks were observed having a blue, clayey appearance. It must be the labor of the most careful observation to distinguish and classify fugitive blocks of this kind, and during my comparatively short visit to this part of the island I was not enabled to make a sufficiently complete collection for this purpose, but I will state that there occurs plentifully in the mixture of erratic blocks, the Chasmopskalken known only there and in the glacial drift of North

Germany. The original bed is no doubt hidden by the waters of the Baltic or has been completely torn away by glacial action. The collection of Professor Geinitz, of the University at Rostock, Germany, is exceptionally rich in fossils from this homeless stone collected from the glacial drift of North Germany. Mr. Andersson, after his studies here, ascribed these blocks partly to a Russian and partly to a Scandinavian origin. He has arranged them in accordance with their relative age in the following groups:

1. Leptæna Schmiditi führenderkalk from Russia.

2. A—Rother Mergelschiefer und kalk mit Trinucleus sp. B.—Graugrüner Mergelschiefer und kalk mit Trinucleus seticornis (both from the Scandinavian Mainland).

3. Macrouruskalk from Russia.

Andersson has given as the principal district for these blocks the southern part of the east coast which accords with my observations. The district which he mentions extends from Nasby near the southern extremity to a point in the north between Stenasa and Sandby. These blocks, however, are to be observed still farther north in the neighborhood of Nord Möckleby, though in not so great a quantity. With the exception of the locality given on the east coast investigators have named no other points on the island at which these stones are found, save small isolated districts at Eriksore and Borgholm, both on the west coast close by the landing place of the steamboats. This fact would seem to show that no very general search had been made over the island for them as yet. These localities are somewhat disturbing to the theory of glacial drift advanced by Andersson, as none of the moraines on this side of the island show evidence of having been left by glaciers coming from Russia, but have come from the northwest or Sweden as will be shown later on. There is, however, no longer need of taking into account the so-called locality at Borgholm. This is mentioned chiefly by Tullberg and he places the point of his find near the "Kulbadhuset" on the beach below the castle.

"Kulbadhuset" is the Swedish for bathhouse. It, therefore, seems probable that he was fond of bathing and while sunning himself after a cool dip in the Baltic discovered the few blocks representing the formation at this point and took them away with him, as a search here revealed only one small piece containing Orthis sp. The assertion that he carried the deposit bodily away may seem an exaggeration, but I assure you that these blocks are usually so rich in fossils that almost every small chip contains a prize, the amount taken depending wholly on the collector's carrying capacity. This point is not more than 100 yards distant from the boat landing.

A list of the fossils collected in a single day from these blocks, called by Tullberg "Younger Chasmopskalken" is as follows:

Chasmops macroura, Chasmops conicophthalmus, Lituites antiquissimus, Lituites Muellaureii, Meristella sp., Turbo rupestris, Pleurotomaria globosa, Cyclocrinus Spaskii, Echinosphærites aurantium, Ambonychia pulchalla, Strophomena deltoidea, Maclurea Logani, a form well known in the Chazy epoch of United States; Platystroma sp., Murchisonia sp., Cyclonema bi-carinatum Hall, Pleurotomaria antiquissima, Pleurotomaria cingulata, Holopea sp., Strophomena imbrex together with several others of the same genus, possibly new, as yet unidentified; Orthis biforata, Rhynchonella capax, Leptæna sericea, Leptæna transversalis, Orthis argentia, Orthis amusi, Orthis flabellum, Porambonite deformatus, Orthoceras sp., Bellerophon (at least three different varieties), Ptychophyllum craigense, Chætetes sp., Philodictya sp. together with several other corals, and many lamellibranchs and trilobites still undetermined.

In order to explain the presence of the blocks of limestone from which the just enumerated fossils were obtained, Andersson has recently made a careful examination of the moraines on the southeastern part of the island. The results of his research appeared in the O. K. V. A. Förhandlingar, Stockholm, for 1893, p. 521. A general observation of the glacial moraines of the island was made at an earlier date by Munthe and Holmström. These show that the general direction in which the glacier moved over the island was S. S. E. This is substantiated by Andersson, but a closer examination of the thick coating of glacial drift, which covers the southeastern part of the island, shows that at a later period the direction of motion was changed and became west or southwest. His chief observations were in a freshly dug grave in the cemetery at Triberga, and in a ditch made recently for drainage purposes to the south of this village. He found in addition to the scratches and furrows which ran in a northerly direction, others which ran in an easterly direction. At the surface in the same neighborhood occurred the fossiliferous blocks already mentioned. It is generally conceded that there were at least three glacial periods over this region. It would, therefore, seem most probable that these furrows were made by the younger or third Baltic glacier described by DeGeer. At this time the entire island was covered completely by glacial ice which moved in a S. S. easterly direction as shown by Munthe, Holström and Andersson's observations. As soon as the melting of the ice had advanced so far that at least the greater part of Oland was ice free (perhaps as a "Nunatak" or bare spot, caused by irregular melting) there resulted a change in the direction of motion to west or southwest. This change of motion was in all probability due to change of pressure brought about by the supposed irregular melting just mentioned. However this may be, we have here at all events a mixture of fossiliferous limestones, some of which were originally deposited in Russia, which lies west of the island across the Baltic Sea, while others come from Sweden. Several Swedish geologists are at present engaged in the study of the glacial period and will no doubt soon clear up all unexplained points.

Granitic boulders from a glacial moraine are being used in the construction of a harbor at Sodra Möckleby. This will to a certain extent destroy the chances for a complete study of the moraines of Oland, though plenty will remain. This moraine has been completely removed for a distance of about one mile and they are still at work on it. The temporary railroad laid to transport the boulders to the coast is the only one on the island. In the north along the east coast it will be noticed that there are numerous tongues of land extending into the sea. Their direction is S. S. E. An examination of several showed them to be of glacial origin, inasmuch as they consist of rounded boulders of granite.

At several points on the island shallow basins were observed. These were lined with an apparently pure, white clay and in wet weather are the sites of small lakes. This clay was formed by the decomposition of the bed rock, an argillaceous limestone. It has in no way been utilized as yet. It is altogether probable that it contains too much carbonate of lime to make brick or pottery, but it could be used to advantage as a fertilizer for the sand lands at the north of the island.

The most recent deposit is seen in extensive peat-mosses or turf beds. These occur only in the region of the lakes in the north. The bog covers considerable territory and extends partly over the waters of the smaller lakes. One experiences a general feeling of insecurity in traversing this region, it being much akin to walking on a spring mattress and although the grass had been freshly mown from its surface a detour of several miles was made to avoid testing the strength of the thinnest portions. These peat mosses are of a comparatively recent growth possibly within the last 500 years, and like many in Ireland are still growing.